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PROJECT APOLLO

WATER MANAGEMENT DURING FLIGHT OF THE APOLLO SPACECRAFT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

Langley Air Force Base, Va.

December 19, 1961

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SUMMARY

This preliminary study was made to establish a water-management program for the Apollo lunar-landing mission. In-flight sources of water are made available from the fuel-cell system and cabin condensate. Water is required for evaporative cooling in certain phases of the mission as well as to satisfy the crew's metabolic and sanitary requirements. It is concluded that the water supply at lift-off will be only the amount required in case of an immediate-abort condition. The in-flight requirements will be more than met by the water produced in the fuel-cell system. Management of the excess fuel-cell water, cabin condensate and initial water provide a source of supplemental cooling.

INTRODUCTION

It is assumed that water is available from four sources: (1) initial storage, (2) condensed excess water vapor in the cabin atmosphere, (3) as a byproduct from the fuel-cell system and (4) urine. Water must be supplied for evaporative cooling while the vehicle is within the earth's atmosphere and must also be available for cooling peak heating loads during flight and on the lunar surface. Water must be supplied to the crew in sufficient quantities to meet their metabolic and sanitary requirements throughout the mission and sufficient water must also be supplied to provide for the crew's metabolic needs during a postlanding recovery period. The vehicle internal heat load, 10,200 Btu/hr is the heat generated by an electrical load of 2 kilowatts, three crew members and the heat of reaction of the lithium hydroxide. Due to the amount of insulation required on the Command Module for reentry, the NASA Manned Spacecraft Center (MSC) Heat Transfer Section indicates that there will be no significant heat transfer to or from the pressurized compartment by passive means. For this study, it is assumed that there was no passive exchange.

DISCUSSION

Water Requirements

At lift-off, the vehicle must contain 65 pounds of stored water to provide for evaporative cooling of the vehicle internal heat load for

exit and reentry through the earth's atmosphere in the event of an abort. The estimated time period for exit and reentry is 45 minutes. The stored water at lift-off must also provide metabolic water for drinking and food preparation for a 72-hour postlanding recovery period at the rate of 6.16 pounds per man-day.

During space flight, the heat load is normally dissipated through a heat exchanger and a space radiator, consequently water is not required for evaporative cooling. Under normal flight conditions, in addition to the 6.16 pounds per man-day of water required for drinking and food preparation, an additional 2.2 pounds per man-day is required for sanitary purposes.

Water Produced Onboard

The fuel-cell system operating under normal conditions of 1.65 kilowatts at 70 percent efficiency supplies more than enough potable water as a byproduct to meet the crew requirements. The excess water vapor in the spacecraft atmosphere is condensed in the heat exchanger, collected and stored for use. Figure 1 indicates the theoretical quantities of water that are required and recovered during flight. Figure 2 indicates the amount of water required for various theoretical cooling rates versus time.

Figure 3 indicates the cooling capacity available by evaporative cooling at lunar touchdown from the accumulated water supply based on a 24-hour period. This accumulated water is the surplus from the fuel-cell and the heat exchanger which was collected during flight. It would be expected that the fuel-cell would operate at 70 percent efficiency which would mean that approximately 97 pounds of water would be available at lunar touchdown. All of this water could not be used on the lunar surface since the surplus water does not accumulate to a sufficient level of 58 pounds during the flight back to earth to meet the reentry and landing needs. The usable water at the moon would provide for cooling approximately 3,600 Btu/hr for the 24-hour period on the moon. To cool the entire heat load on the lunar surface for 7 days would require in excess of 1,400 pounds of water to be stored onboard at lift-off.

It should be noted on figure 3 that in the event the fuel-cell operates at a reduced efficiency, it does not jeopardize the water balance but in fact assists by supplying additional water at the cost of higher reactant consumption rates.

It is not planned at this stage to employ urine as an evaporative coolant; but the urine collected in flight should be available for use as an emergency coolant.

CONCLUSIONS

A minimum prelaunch water supply of 65 pounds must be available for the emergency condition of an immediate abort, reentry and 72-hour recovery period.

By using the byproduct water from the fuel-cell and recovery of the excess water vapor from the cabin air, sufficient water is available to meet all expected normal in-flight needs.

By conservation of the water, supplemental cooling at a rate of 3,600 Btu per hour is available at lunar touchdown for a period of 24 hours.

Reentry cooling and recovery period requirements dictate the necessity of an available water supply of 58 pounds prior to reentry.

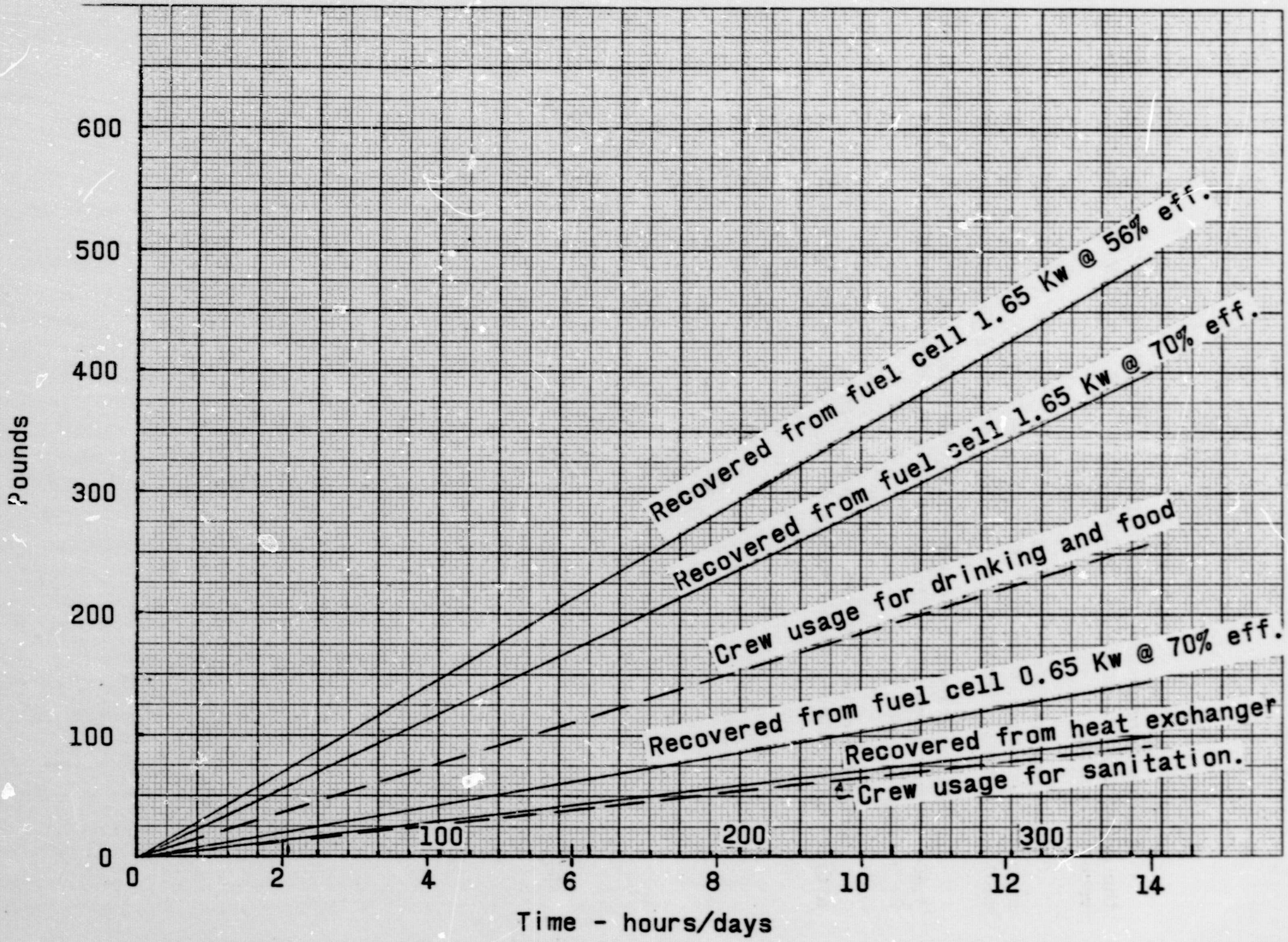

Figure 1. - Theoretical water recovery and usage.

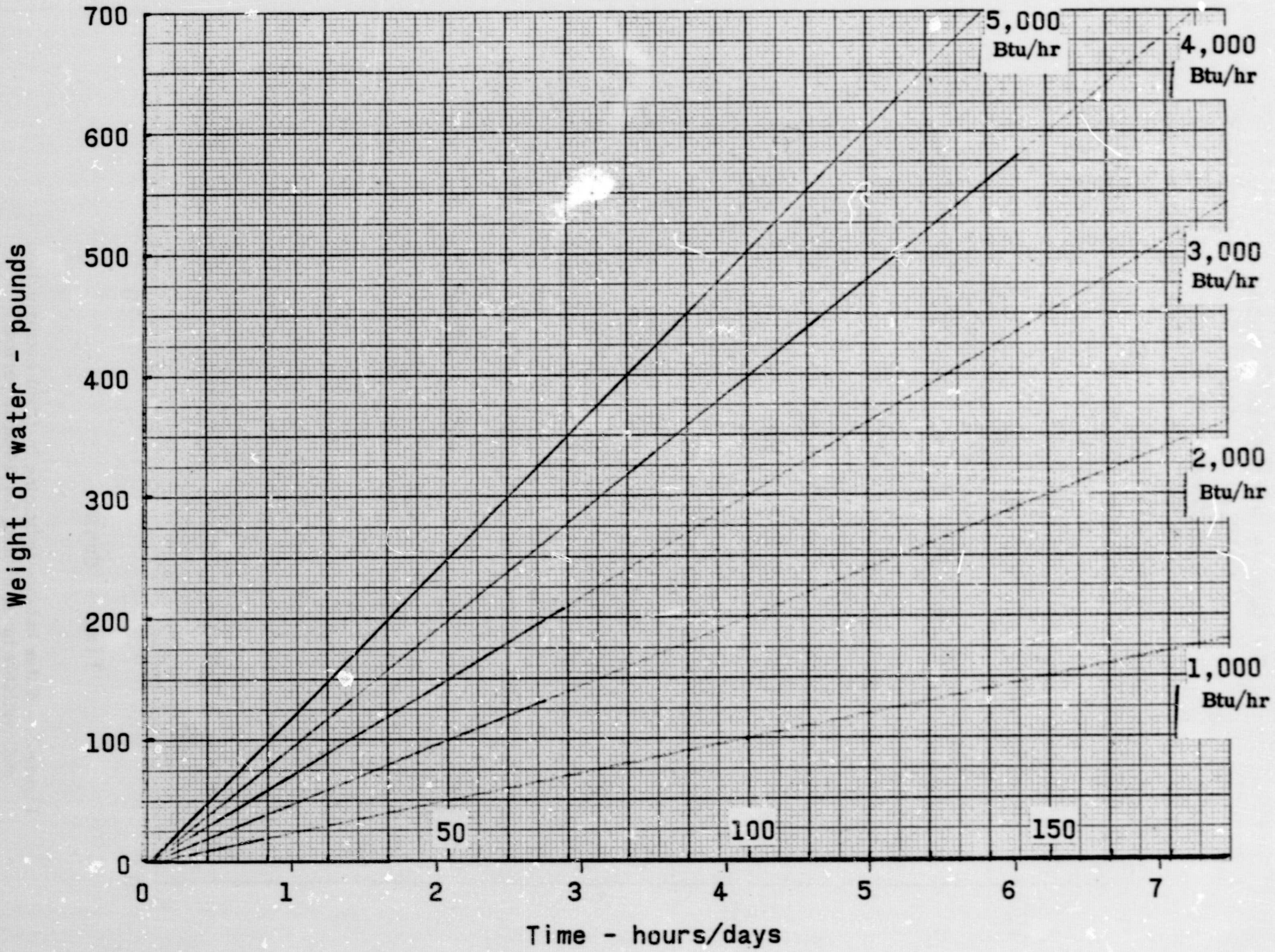

Figure 2. - Theoretical cooling by water evaporation.

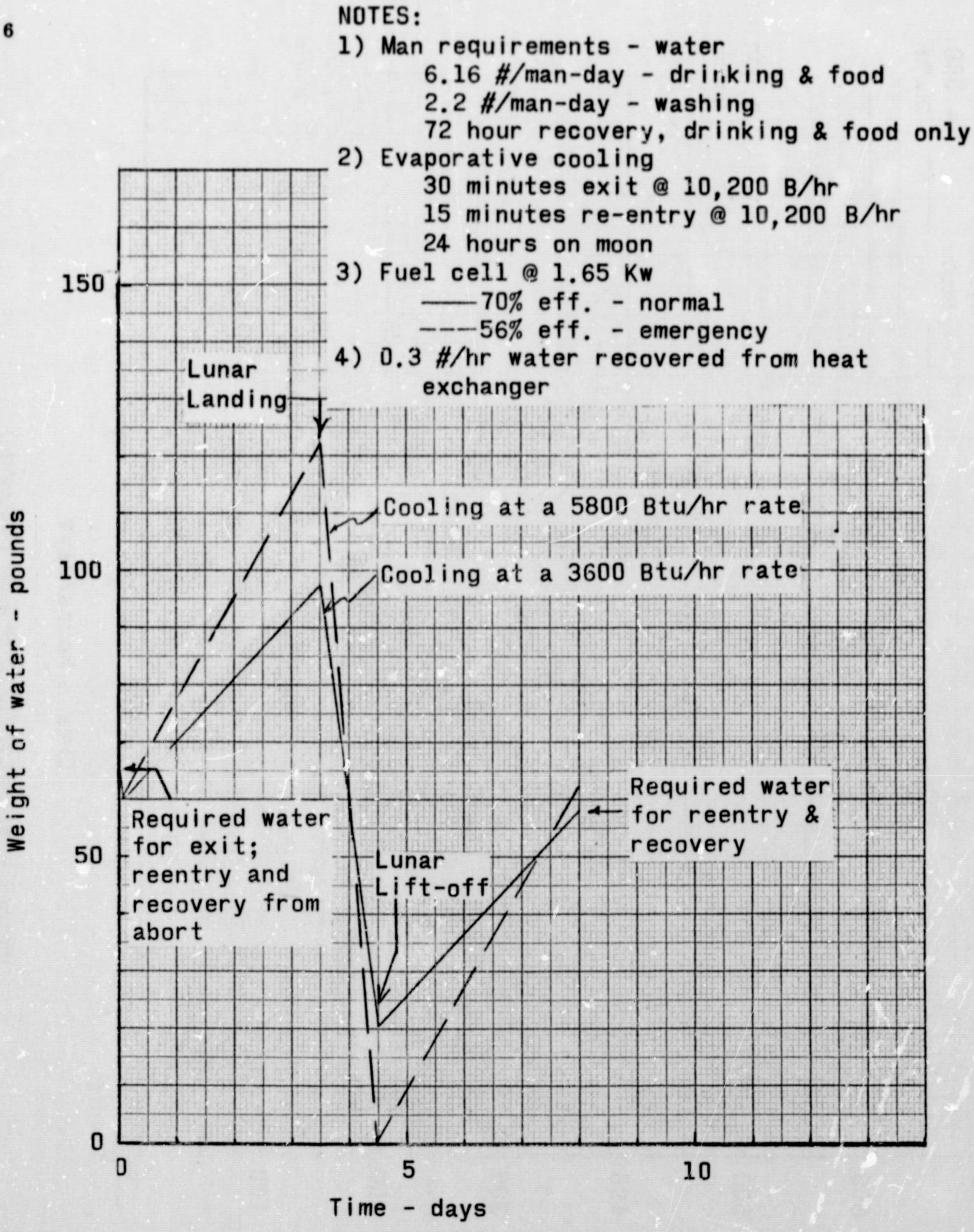

Figure 3. - Water balance indicating in-flight accumulation and available lunar cooling for 24-hour period.